

USE OF AN ACOUSTIC RANGING SYSTEM TO MONITOR SEDIMENT DEPOSITION AND EROSION FOR THE PROTECTION OF AN ENDANGERED MUSSEL BELOW THE OLMSTED LOCKS AND DAM, ILLINOIS



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U.S. Department of the Interior—U.S Geological Survey

INTRODUCTION

Background

The Ohio River flows 981 miles (mi) from the confluence of the Allegheny and Monongahela Rivers at Pittsburgh, Penn. to the Mississippi River near Cairo, Ill. The entire river, except for the last 19 mi (from Lock and Dam 53 to the Mississippi River), has been altered by construction and operation of locks and dams to provide a stable navigational channel. During the past 50 years, all but two of the original wooden wicket dams and locks have been replaced with high-lift dams. Current traffic demands are continuing to grow and it is becoming impossible to meet this need because of the archaic design of the original wicket dams and locks. Periodic improvements will continue to be needed for the waterways transportation infrastructure. The lower Ohio River is very important in that it provides the connection between the Cumberland, Mississippi, Ohio, and Tennessee Rivers. This reach of the inland navigation system has more tonnage passing through than any other reach on the lower Ohio River. Increases in pool elevations on the Ohio River that border the Commonwealth of Kentucky are a result of the new high-lift dams shown in figure 1.

The Ohio River and its tributaries have historically supported a multitude of aquatic species including fish and mussels. Construction of navigation facilities significantly altered the river's natural condition. Extensive artificial impoundments of the river slowed current velocities, and subsequent accumulation of silt resulted in reductions in mussel fauna (Thorp and Covich, 1991). The lower Ohio River, from Lock and Dam 53 to its confluence with the Mississippi River, contains the only remaining free-flowing riverine habitat in the entire mainstem of the river and supports the largest populations of pre-impoundment fish and mussel species (U.S. Fish and Wildlife Service, 1993).

On the basis of investigations to improve navigational conditions on the lower Ohio River, the U.S. Army Corps of Engineers (COE), Louisville District, was authorized to replace Locks and Dams 52 and 53 with a

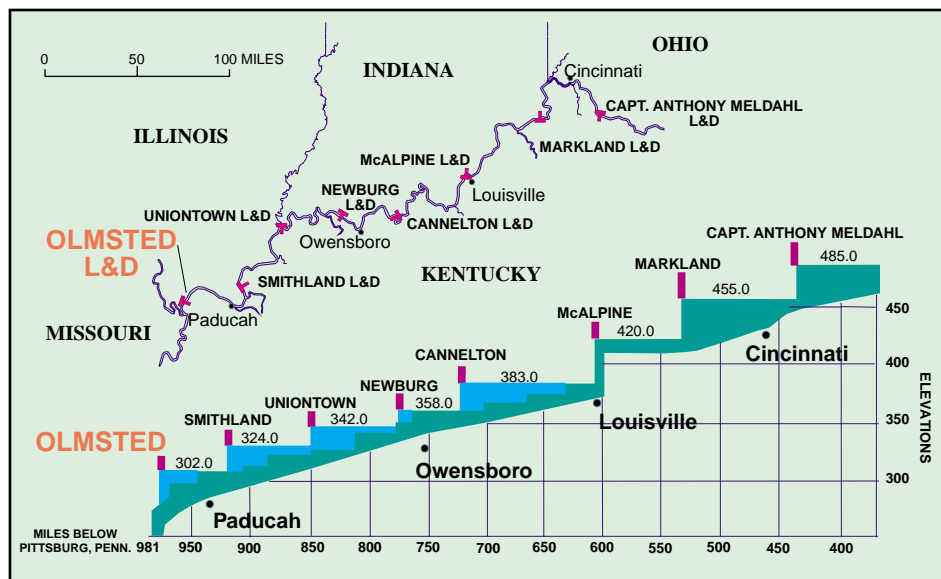


Figure 1. Increased pool elevations as a result of high-lift dams being constructed on the Ohio River.

single structure. This new facility will be located at Ohio River Mile 964.4, near Olmsted, Ill., and will be known as Olmsted Locks and Dam. Construction of the Olmsted Locks and Dam was authorized by the United States Congress on November 17, 1988, when the Water Resources Development Act of 1988 was passed. The facility is about 1.8 mi downstream of the present Lock and Dam 53. The plan currently being considered will

consist of the following: two parallel lock chambers about 110 feet (ft) wide by 1,200 ft long constructed on the Illinois side of the river, five tainter gates about 110 ft wide, a 1,400 ft navigable pass section, steel wickets, and a section of fixed weir on the Kentucky side of the river. An aerial photograph (Illinois shore) of the coffered area (41 acres) where construction of the two 1,200 ft long locks has begun is shown in figure 2. An artist's rendition



Figure 2. Coffered area where construction of two 1,200 ft locks are being built.



Figure 3. Artist rendition of the completed Olmsted Locks and Dam near Olmsted, Ill.

of the future Olmsted Locks and Dam is shown in figure 3. The navigational pool created by the new dam will be operated to maximize use of the navigable pass and minimize frequency of lockage. Upon completion of the Olmsted Locks and Dam, the present Locks and Dams 52 and 53 will be dismantled and removed from the Ohio River.

This fact sheet describes the unique application of a multi-transducer acoustic ranging system interfaced with Geostationary Operational Environmental Satellite (GOES) telemetry for monitoring sediment deposition and erosion characteristics of a mussel bed near the Olmsted Locks and Dam, Ill. The sediment deposition monitoring system determines riverbed elevations at remote sites and transmits the data to various offices around the country.

Problem

The endangered orange-footed pearly mussel (*Plethobasus cooperianus*) shown in figure 4 is an Interior Basin species that reaches an average adult size of about 2.5 inches (in.) and is usually found in medium to large rivers at depths of 10 to 29 ft (U.S. Fish and Wildlife Service, 1993). The mussel buries itself into sand and gravel leaving only part of its shell and feeding siphon projecting above the riverbed. The Ohio, Cumberland, and Tennessee River drainages contain the only three known

population areas of this mussel remaining anywhere in the historic range of the species. The only known reproducing population is in the Tennessee River (U.S. Fish and Wildlife Service, 1993).

The two mussel beds (one population) located in the lower Ohio River near the Olmsted Locks and Dam (currently under construction) are suspected to be reproducing, so any adverse effect on this population could threaten the survival of the species. This investigation is concerned with the mussel bed located downstream of the Olmsted Locks and Dam. The mussel bed is on the right



Figure 4. Endangered orange-footed pearly mussel (*Plethobasus cooperianus*).

descending bank with its center near the inflection of two opposing bends in the river. These bends have a very large radius (small curvature). The upper end of the mussel bed begins along the outside, downstream edge of the upstream bend. The mussel bed extends through the crossing and terminates on the inside of the downstream bend. Sediment deposition and erosion patterns that were present prior to construction may change because of the following: bed material lost during dredging for cofferdam construction, creation of a temporary navigational channel, changes in the water-current direction and magnitude, associated river traffic, and riverside development during the

construction and operation of the new locks and dam. Changes to the sediment regime could result in water-quality degradation and habitat alteration. The guidelines in the biological opinion (U.S. Fish and Wildlife Service, 1993), set forth by the U.S. Fish and Wildlife Service (USFWS) to ensure protection of the mussels, state that if one sensor indicates an hourly accumulation of 0.787 in. above baseline levels on the mussel bed and if the accumulated sediment remains at the elevated level or increases over another 3-hour period, construction activities will cease and corrective actions will be taken. It has been documented that all data collected from August 1993 to the present (1997) is naturally occurring and current construction activities have not altered the sediment deposition and erosion patterns.

Monitoring Plans

To ensure continued viability of the mussel beds, the COE implemented a system designed to monitor the mussel populations and record effects of project construction and developed a contingency plan if certain criteria were not met. Biological monitoring, consisting of qualitative and quantitative sampling of the mussels, will be conducted for the first 2 years (1993–94) and in alternate years thereafter for the remainder of the construction and initial operation period of the Olmsted Locks and Dam (U.S. Fish and Wildlife Service, 1993). Physical monitoring also will be conducted by the COE, which includes hydrographic surveys

to map the position and extent of the mussel beds; the mapping surveys will provide detailed contours for the development of three-dimensional models of the beds. The U.S. Geological Survey (USGS) and the Louisville District COE, designed and installed a multi-transducer acoustic ranging and telemetry system to continuously monitor the changes in elevation of the riverbed over the mussel bed located downstream of the construction site. Construction activities started in September 1993 and the system is currently collecting baseline data during the Stage I period of construction scheduled for completion in the year 2000. The system will continue to be operated during construction and during normal lock and dam operation until such time that it is determined that the routine operation of the facility is not adversely affecting the mussel bed by sediment deposition or erosion. To meet the guidelines of the biological opinion issued by the USFWS regarding protection of the endangered mussel species (U.S. Fish and Wildlife Service, 1993), the monitoring system must (1) provide real-time riverbed elevation data, (2) detect 0.787 in. of sediment deposition at remote locations on the Ohio River, and (3) provide the data to personnel in various locations.

SYSTEM DESIGN

Physical Configuration

Six transducers are positioned in a "T" configuration (fig. 5) with the base of the "T" pointing upstream in each of the two groups; the two groups are located near the mussel bed. Each segment of the "T" has two transducers equally spaced over a distance of 350 ft. A 5/16-in. diameter steel carrier cable was laid between a mooring pile at the center of the cluster and each of the transducer stands. The steel carrier cable helped secure the transducer cable and was used as a guide for divers to locate the transducer stands. The profile view of the transducer stand consisting of a 6-in. H-pile driven into the riverbed with a 3-ft long I-beam bolted to the H-pile in a horizontal position about 4 ft above the riverbed and pointing upstream is shown in figure 6. The transducers were mounted to a stainless-steel bracket attached to the upstream end of the I-beam. Kevlar reinforced transducer cable, with mating underwater pluggable connectors, was used to connect the transducer to the surface electronics and was attached to the 5/16-in. stainless-steel carrier cable with nylon-wire straps. The buoys (fig. 7) have a 12-ft diameter horizontal-deck platform and are 11 ft long. The buoys are designed to withstand velocities of 10 feet per second (ft/s), have a payload capacity of 2,000 pounds, and the decks extend out of the

water about 3 ft. They have an adjustable ballast feature. The instrument box enclosure was designed into the construction of the buoys and is located below the platform deck. A specially designed 42 × 42 in. waterproof aluminum box rests inside the enclosure and can be easily removed. A spring-balanced aluminum hatch cover allows entrance to the instrumentation enclosure. The buoys are moored by a 5/8-in. steel cable to the 10-in. H-pile driven into the riverbed. The buoys have a skid-proof surface, handrails, and a U.S. Coast Guard approved navigation light for safety.

requires elevation data to be collected at numerous points over the mussel bed. Several technologies were evaluated, and the acoustic ranging systems were found to be the most cost-effective method of monitoring the change in riverbed elevation. The equipment had to (1) be rugged, (2) provide the required measurement accuracy over a broad range of environmental conditions with minimal manual adjustment, and (3) operate with low power consumption. To minimize damage caused by submerged debris, all electronics except the transducers had to be located above the water surface. The cable used for the transducers had to be armored to provide strength while maintaining cable flexibility. Each transducer would have a 6-ft pigtail, with underwater

Acoustic Ranging System

Monitoring changes in riverbed elevation

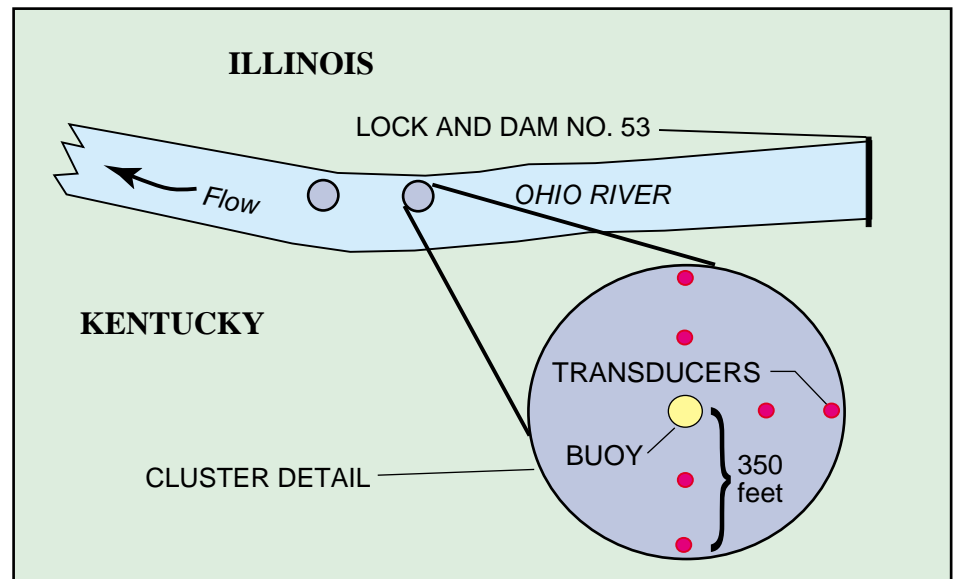


Figure 5. Physical configuration (plan view) of the mussel-bed monitoring system.

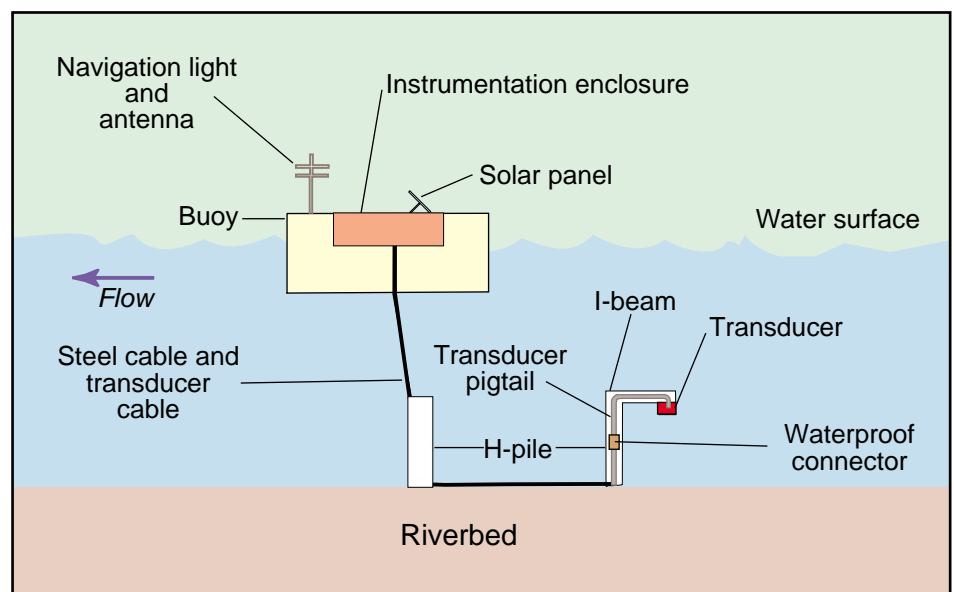


Figure 6. Physical configuration (profile view) of the mussel-bed monitoring system.



Figure 7. Buoy housing the mussel-bed monitoring equipment on the lower Ohio River.

pluggable connectors, for ease of installation and maintenance of the transducers. The connector serves as a weak link in the event that debris catches on the transducer cable. Each transducer operates independently to minimize data loss. The minimum and maximum operating range of the system was an important factor in how far above the riverbed the transducers were mounted. The higher the transducer is mounted, the more likely it is to be damaged by debris; however, if it is mounted too low, the transducer could become buried during extreme sediment deposition. It was decided that the transducers would be mounted about 3.5 ft above the riverbed.

Accurate detection of 0.787 in. of sediment accumulation required the acoustic ranging system to have an accuracy of ± 0.394 in. in environmental conditions typical of the Ohio River. Most acoustic ranging systems measure the depth to the nearest object that reflects sufficient acoustic energy to exceed a predetermined energy threshold. The effect of false-bottom readings resulting from fish or submerged debris is minimized by the acoustic ranging system that was configured to (1) measure the riverbed elevation every 2 minutes; (2) rank the data from minimum to maximum for each hour; and (3) determine the hourly minimum, maximum, and median elevations. The hourly data are monitored for changes in the riverbed elevations. The acoustic ranging system was designed to provide internal data storage for 3 to 6 months. A single RS-232 interface was available to download data and to change setup parameters for the instrumentation.

The Model PSA-902 Multi-Channel High Resolution Acoustic Ranging System by Datasonics, Inc., was selected for this application. The PSA-902 provides internal data storage using a 128K byte memory card

and includes an internal-battery backup in the event of external power failure. The transducers operate at a frequency of 200 kilohertz (kHz), and the system has a stated resolution of 0.394 in. and a range of 0.98 to 98.4 ft. The PSA-902 operates on 24 volts ± 2 volts direct-current (VDC) at 100 milliamps and provides 12 hours of battery-backup power. The PSA-902 can handle up to 16 different transducers; communication with the PSA-902 is through a personal computer (PC) compatible RS-232 port. Custom firmware was provided by the manufacturer to facilitate the measurement scheme required for this application. Transducer cable was reinforced with Kevlar and can carry the acoustic signal up to a distance of 2,000 ft.

Remote Communications

The remote communications had to interface with the PSA-902 Acoustic Ranging System, provide redundant data storage, and provide routine hourly data and battery voltages to various offices through the GOES system. The Handar 555A is a Data Acquisition System (DAS) designed for remote data acquisition that collects and processes environmental data and transmits that data to remote locations for analysis in near real-time through the GOES system. The Handar 555A contains a GOES radio that will transmit the hourly data every 2 hours by satellite. The Handar 555A is the terminal strip version with access to all inputs and outputs. It has a NEMA-4x rated fiberglass enclosure and requires a 12-volt power source. Communication between the Handar 555A and the PSA-902 is done through a PC compatible RS-232 port.

Power System

The power system used for the sediment deposition monitoring system, consisting of the PSA-902 and the Handar 555A, includes the combination of batteries, solar panels, voltage regulators, and DC to DC converters. Each buoy has four 12-volt 100-amp hour sealed lead-acid batteries connected in parallel. The batteries are recharged by two 50-watt solar panels mounted at a 45-degree angle. Solar panels constructed without glass are used to ensure durability in the remote environment. The solar panels are connected to a voltage regulator that uses a blocking diode to prevent battery discharge through the solar panels. The DC to DC converter is used to convert the 12

volts from the voltage regulator to 24 volts required to power the PSA-902. This power system setup would provide about 21 days of power with the batteries operating at 75 percent capacity.

SUMMARY

The construction and operation of the Olmsted Locks and Dam near Olmsted, Ill. may have an affect on two mussel beds located near the project site. These mussel beds contain the endangered orange-footed pearly mussel (*Plethobasus cooperianus*). Guidelines set by the USFWS, to ensure protection of the mussel beds, state that sediment accumulations cannot exceed 0.787 in. above baseline levels. The USGS and the COE designed and installed a system to continuously monitor changes in elevation of the riverbed over the mussel bed located downstream of the Olmsted Locks and Dam project. The system utilizes a multi-transducer acoustic ranging system to provide riverbed elevation measurements accurate to ± 0.394 in. Therefore, the acoustic ranging system is providing adequate data for monitoring a 0.787 in. change in riverbed elevation. Data from the acoustic ranging system are transmitted every 2 hours using the GOES system. The system is currently collecting data to assess the baseline sediment deposition and erosion characteristics of the downstream mussel bed. It will continue to be operated during construction and normal lock and dam operations until it is determined that routine operation of the facility is not adversely affecting the mussel bed by sediment deposition or erosion.

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